Memorandum

U.S. Department
of Transportation

Federal Aviation
Administration

Subject: **ACTION**: Review and Concurrence, Equivalent Level of Safety Finding for Cessna New Model 680; Thrust Reversers
FAA Project #TC2548WI-T

Date: July 12, 2004

Reg Ref: §§ 25.933, 25.1309, 25.571

From: Manager, Propulsion/Mechanical Systems Branch, ANM-112

Reply to Attn. of: Bob Adamson, ACE-118W

To: Manager, Wichita Aircraft Certification Office, ACE-115W

ELOS Memo #: TC2548WI-T-P-6

Background:

The Model 680 thrust reverser (T/R) system consists of two fixed pivot, integral nozzle, target type thrust reversers controlled by aircraft supplied hydraulic and electrical inputs. The T/Rs have two primary design features to prevent unintended in-flight deployment:

1) The T/R command system was designed with a multiple lines of defense philosophy, meaning a minimum of two system failures are required to cause an unwanted deployment.
2) The door latch mechanism includes hooks, requiring the doors to be hydraulically 'over stowed' (i.e. pulled toward engine centerline) to allow the hooks to retract from the door latch receptacles. The aerodynamic loading on the thrust reverser doors, which is a function of altitude, airspeed and engine power, is such that the thrust reverser actuation system is not capable of "over stowing" the doors outside of a limited "overstow envelope". Consequently, even if commanded to deploy, the thrust reverser would remain stowed under most flight conditions.

Cessna initially requested a finding of equivalent level of safety (ELOS) to § 25.933(a)(1)(ii) for the Model 680. That finding was to be based on reliability, which would be supported by addressing system reliability, maintainability, fault tolerance, structural integrity and protection against zonal threats as applicable. This equivalent level of safety request resulted in FAA Issue Paper (P-6).

Cessna later elected to show direct compliance with § 25.933(a)(1)(ii). However, Cessna elected not to demonstrate deployments outside of the "overstow envelope" where unwanted in-flight thrust reverser deployment would require structural failures within the door lock mechanisms. Consequently, Issue Paper P-6 was determined to still be appropriate for those portions of the flight envelope where the assurance of continued safe flight was dependent upon demonstrating the reliability of the structure rather than the controllability of the airplane.

This equivalent safety finding focused on validating:

1) that outside the "overstow envelope"(within which controllability was demonstrated) the thrust reverser hydraulic system will never be capable of "overstowing" the reverser doors; and

2) the load paths by which the thrust reversers are held stowed in flight have adequate integrity and redundancy to assure they will not fail to perform that function within the fleet life of the airplane type.

Regulation requiring an ELOS:

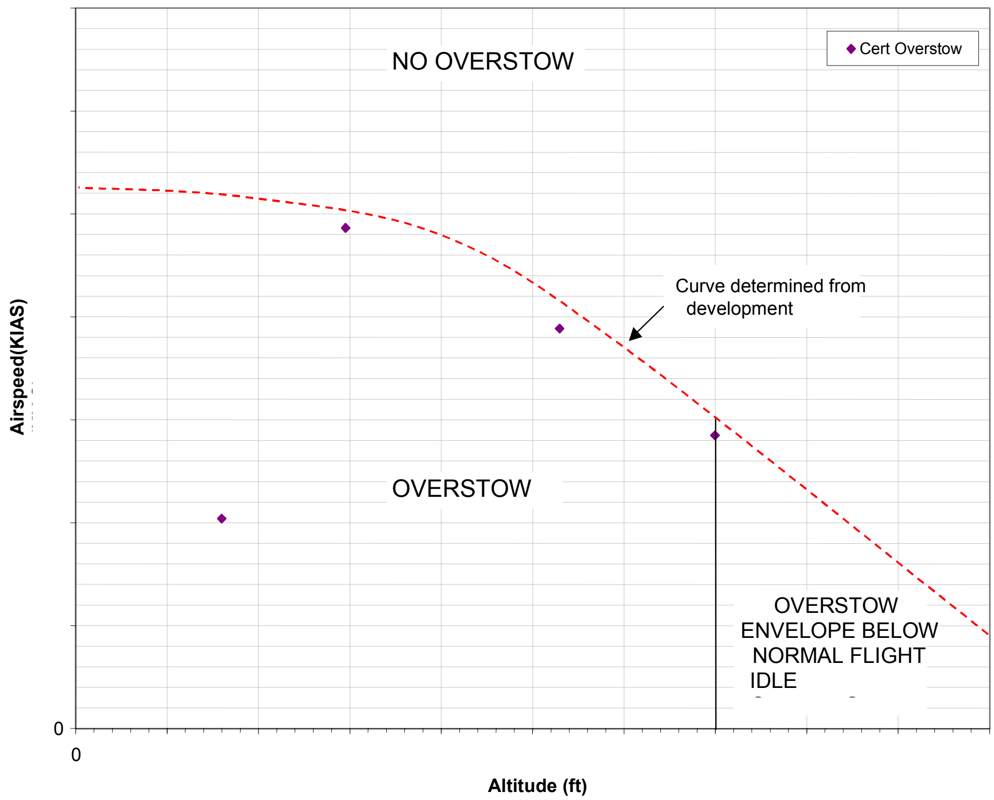
Sections 25.933(a)(1)(ii) – Reversing Systems

Description of compensating design features or alternative standards, which allow the granting for the ELOS (including design changes, limitations or equipment need for equivalency)

"Overstow Envelope"

The T/R primary actuator has been sized such that at thrust settings greater than idle or airspeed above a given amount (defined as the overstow airspeed), the pressure on the inside of the T/R doors or the negative aerodynamic pressure on the outside of the T/R doors, or a combination of both is greater than the actuator can overcome, preventing the overstow requirement needed for unlatch and deployment of the doors. Flight test has defined the overstow envelope for the aircraft. If the airspeed is above this envelope, the T/R cannot deploy. Therefore, barring multiple structural failures in the door latch mechanism, the only possible position of the T/R, even if commanded to deploy, is stowed. Flight testing has shown that there are even thrust setting and aircraft speed combinations within the overstow envelope where the T/R cannot deploy.

In addition to the overstow envelope defining where the T/R could deploy with the engine at idle, if the engine speed is above approximately 60% N1, the nozzle pressure is high enough at all airspeeds to prevent the T/R overstow motion and this also prevents the T/R from being able to deploy. Therefore at all airspeeds when the engine speed is above 60% N1, barring multiple structural failures within the door latch mechanism, the only possible position of the T/R is stowed. This provides an additional level of protection for the aircraft during the takeoff phase of flight. The significance of the overstow envelope is that for a T/R to deploy above the overstow envelope would require failure of multiple critical T/R structural components, which is entirely independent of system failures. The portions of the Model 680 Mission Profile where the aircraft might be in the overstow envelope are limited to Approach, and Landing. Compliance was demonstrated for deployments within this overstow envelope.



Thrust Reverser Overstow Envelope

Structural Integrity and Redundancy of Reverser Door Lock Mechanism

Each T/R door is restrained at 4 points while it is stowed. These restraining load paths were designed to meet all applicable structural requirements. Consequently, no single failure of the thrust reverser structure can cause the failure of remaining structure, thus the doors will not deploy. Defined visual inspection of the support structures is sufficient to meet the damage tolerant requirements of 14 CFR 25.571.

Latch Housing Failure

Stress analysis performed on the latch housing shows that each latch housing supports an upper and lower door hook. The housing was analyzed for a normal flight load at 355 KCAS and max take-off power, with a latch failed on the opposite side. With this one latch holding the door shut it maintained an adequate margin of safety in both compression and tension. A fatigue analysis was also performed using conservative stress levels.

Latch Hook

Stress analysis performed on the hook shows that each hook (each door has two hooks) was analyzed for a normal flight load at 355 KCAS and max take-off power, with a latch/hook failed on the opposite side. With the remaining hook holding the door shut it maintained an adequate margin of safety in both compression and tension. A fatigue analysis was also performed using conservative stress levels.

<u>Latch Receptacle</u>
Stress analysis performed on each latch receptacle also provided adequate safety margins

Additional structural testing was performed specifically to support this equivalent safety finding. This testing demonstrated that with any two structural components failed the remaining T/R structural components were adequate to provide continued safe flight and landing. The two forward latches are necessary for keeping the door stowed fully flush in flight. If both latches fail the load will transfer thru the linkage and hinge to the other door. This softer load path may allow a slight opening of the failed door. If either of the two aft supports (hinges) fail, the door may deflect outward at the aft end and load will transfer to the link. This position will not catch air that would try to force a deployment.

The reverser restraints were also found to be capable of preventing an unwanted deployment should an engine uncontained rotor failure event occur.

Explanation of how design features or alternative standards provide an equivalent level of safety intended by the regulation.

Even if an airplane is found compliant with the subject regulation (i.e. it's clearly controllable), an unwanted thrust reverser deployment still poses some risk to the airplane due to the potential for associated crew error or the presence of unrelated exacerbating factors (e.g. a flight control failure that reduce the control margin of the airplane). Consequently, by effectively preventing the occurrence of any unwanted thrust reversal outside of the overstow envelope, this risk is eliminated. However, this certification approach introduces a very small risk that despite all the design precautions, a deployment could still occur within a flight envelope that has not been shown to be controllable. It was the balance between these two risks, which was considered in finding that the Cessna design provides an equivalent level of safety to a completely compliant design.

<u>Conclusion – § 25.933(a)(1)(ii):</u>

The Model 680 is capable of safe flight and landing with a T/R deployed within the overstow envelope shown above, thus providing direct compliance with § 25.933(a)(1)(ii) for that part of the flight envelope. Acceptable compensating factors that support an equivalent level of safety to § 25.933(a)(1)(ii) have been established for the Model 680 when the airplane is the operating outside the overstow envelope (i.e. within the no overstow envelope) as follows:

- The T/Rs have been demonstrated to not deploy with pilot commands or system failures due to aerodynamic loads when the aircraft is operated outside the overstow envelope.
- The components and structure, whose structural failure could result in T/R deployment, have been demonstrated to be reliable by tests and analysis establishing structural integrity and effective redundancy.

FAA approval and documentation of the ELOS:

The FAA has approved the aforementioned Equivalent Level of Safety Finding in Issue Paper P-6. This memorandum provides standardized documentation of the ELOS that is non-proprietary and can be made available to the public. The Transport Directorate has assigned a unique ELOS Memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS Memorandum Number should be listed in the Type Certificate Data Sheet under the Certification Basis section. [E.g. Equivalent Safety Findings have been made for the following regulations: § 25.933(a)(1)(ii) – Reversing systems (documented in TAD ELOS Memo TC2548WI-T-P-6)]

/s/

Signature: Neil D. Schalekamp
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Date: July 12,, 2004

ELOS Originated by Wichita ACO:	Program Manager, Tina Miller	Routing Symbol ACE-117W

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